Personal Statement

Michał Dereziński *NSF application*

Growing up in an academic household with my father being a professor of physics, I have always appreciated the beauty in logic and science. My interest in computer science began with the famous question *Can machines think?* proposed by Alan Turing. Although there is still no clear answer or even a formal description of this problem, there is a significant progress in the way computers can understand and analyze abstract concepts used by humans. This inspired me to study modern natural language processing and knowledge representation techniques. When I started my research on structuring information into concept hierarchies, I decided to focus my graduate work on artificial intelligence.

My research on artificial intelligence began when I started attending a seminar on natural language processing at the University of Warsaw. While studying methods for unsupervised extraction of knowledge from text, I learned about applications of Formal Concept Analysis to fuzzy data sets. These methods were promising but inefficient for my task, so I developed a new algorithm for unsupervised concept hierarchy generation, which eliminated some of their problems. This became my master's thesis. After defending my thesis I continued to work in this area. I devised a semi-supervised technique for improving concept hierarchy through active learning. I presented this work in a talk entitled *Active Semi-Supervised Concept Hierarchy Refinement* at the First International Workshop on Learning with Weak Supervision in Singapore in November 2012. I intend to publish these results in a near future. My other interests in machine learning include the recent advances in deep neural networks and probabilistic approaches to classification. In September 2012 I attended the European Conference on Machine Learning in Bristol. This allowed me to make myself familiar with the current state of research and the scientific community of machine learning.

I studied mathematics in parallel with computer science. In my opinion, it enhances my computer science skills. It is worth noting that mathematics plays a significant role in machine learning. However, I am interested in math also for its own sake. I enrolled in various advanced courses covering all major areas of mathematics, with very good results. My master's thesis research was in the area of harmonic analysis. The problem that I was given withstood traditional mathematical approaches, so I had to think outside of the box to find the solution. My first attempt, was a computer algorithm which involved analyzing millions of possible cases. Even though this first approach did not turn out to be fruitful, I did not get discouraged and decided to go about the problem in a completely different way. I think it is important to take risks and use unusual methods to pave the way for scientific advances. This allowed me to make significant progress in my research in both mathematics and computer science.

My first work experience was in Santa Clara, California, where I was a software engineering intern at Nvidia in the Summer 2010, 2011 and 2012. While I was in Silicon Valley, I joined an Internet-based start-up, where I was assigned a project that involved natural language processing and data mining. I was glad that I could use my theoretical knowledge in a practical scenario, even though this was a very different experience than my research work.

I have just began my Ph.D. studies at University of California, Santa Cruz, but I have already involved myself in a very innovative new research project on face detection and gaze tracking. The goal of the project is to help students learn more efficiently while reading scientific books and documents on their computers, by automatically analyzing their gaze patterns and facial features to find out what parts of the text they find most interesting, challenging or important. With this information a computer program would be able to highlight the parts of text which the student should revise most carefully.

With my passion for science, as well as expertise in both artificial intelligence and mathematics, I think that during my graduate study as an NSF fellow I can make valuable contributions to computer science.

Proposed Research

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The motivation for my current research came from my own practical need. As a student, I have to read a lot of research papers, digitized textbooks and other scientific documents. However, just reading them once is often not enough. Students need to review the material before exams, look up facts and definitions in previously read papers. My goal is to create software algorithms and interfaces which would allow us to find information in previously read documents faster and more conveniently, based on the information about our behavior during the first time we read those documents. The main concept which made me believe such a project would be valuable is gaze tracking. It is a computer science research field whose aim is to calculate the trajectory of points on a computer screen that is followed by the eyes of the person looking at the screen. The gaze behavior of a person reading a document provides a vast amount of information about which sections they find most important or interesting, and which keywords ought to be remembered mostly.

Gaze tracking has many potential applications that are explored by researchers and technology companies all over the world. In most cases it requires expensive specialized hardware to be performed accurately. The eye trackers sold by Tobii, one of the industry leaders in the field, allow scientists to, for example, develop new innovative human-computer interaction methods ([1]) or to analyze advertisement engagement ([2]). However, the ideal scenario for gaze tracking to become ubiquitous in modern technology would be to use the cameras built into the modern laptops and tablets. Unfortunately, the best approaches so far have not been very accurate ([3]). I intend to overcome this problem by narrowing the task of gaze tracking to the specific scenario of reading text documents. When we read, the gaze trajectory follows a very predictable pattern. This should allow for a significant noise reduction of measurements, if we employ machine learning to predict the most likely trajectory based on the given aproximate data. This approach requires developing a new machine learning algorithm, which could potentially have other applications for predicting trajectories, and it would also be an interesting expansion of theoretical learning theory.

Eye tracking is not the only relevant information that can be obtained about a person's behavior when reading. Other facial features can be a good indicator of whether a person is deep in thought, confused or uninterested. Matching these reactions with the specific section of the text being read gives us a better assessment of what is the most relevant information in the document. Face recognition is easier than gaze tracking, so there are many software products providing such functionality, like the one created by Visage Technologies.

Developing an application that would be practical for students presents other challanges, like designing a good interface or creating algorithms for analysing the structure and contents of scientific documents. I hope that I will get a chance to work alongside other talented researchers, whose espertise would be invalueable in completing such a project. I think that the results of my work could benefit many students and scientists in their pursuit of knowledge.

References

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